Jet Quenching and Azimuthal Anisotropy of Large p_T Spectra in Non-central High-energy Heavy-ion Collisions *

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In the study of the dense matter that is created in high-energy heavy-ion collisions, one crucial issue is the degree of thermalization through secondary scatterings. If thermalization has been, at least partially, achieved, there should be collective effects developed through the evolution of the system. Azimuthal anisotropy in hadron spectra or elliptic flow has been proposed as a good signature of collective transverse flow in relativistic heavy-ion collisions. Such an elliptic flow has been observed in experiments at the BNL/AGS, CERN/SPS and most recently BNL/RHIC by the STAR experiment. The strength of the elliptic flow, v_2, experimentally defined as the second coefficient in the Fourier decomposition of the particle azimuthal distribution with respect to the reaction plane, was found to be between the limits of low-density rescattering and hydrodynamic expansion, indicating approach to a higher degree of thermalization with increasing colliding energies. At RHIC energies, one expects to see v_2 becoming closer to the hydrodynamic limit as the initial energy density increases and the lifetime of the initial dense matter is getting longer. Because system evolution will eliminate the geometrical anisotropy which generates the anisotropy in momentum space, the elliptic flow was argued to be sensitive to the early dynamics of the system.

In hydrodynamic models, the strength of the differential elliptic flow, $v_2(p_T)$, increases almost linearly with p_T because of collective expansion. At large transverse momentum, the hydrodynamic model will likely cease to be a valid mechanism for particle production in high energy nuclear collisions. Instead, particle production at $p_T > 2$ GeV/c will be dominated by hard or semihard processes. Parton energy loss will cause the suppression of large p_T hadron spectra which will depend on the average distance that partons propagate inside the medium during the lifetime of the dense matter. Since the transverse distance depends on the azimuthal direction of the parton propagation in non-central heavy-ion collisions, one should expect the hadron suppression caused by parton energy loss to depend on the azimuthal angle with respect to the reaction plane, thus leading to azimuthal anisotropy in high p_T hadron spectra.

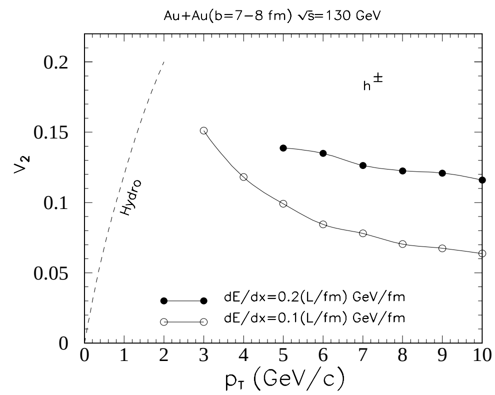

Figure 1: The p_T dependence of the coefficient of azimuthal anisotropy v_2 for charged hadrons for different values of parton energy loss in semi-peripheral $Au + Au$ collisions at $\sqrt{s} = 130$ GeV. The dashed line is the hydro result.

In this paper, we will study the azimuthal anisotropy in hadron spectra at large p_T using a parton model in which one incorporates the parton energy loss via modified parton fragmentation functions.

For a parton energy loss dE/dx that has a weak dependence on the parton energy, we found that the hadron spectra suppression and the accompanying azimuthal anisotropy should all decrease with p_T, as shown in Fig. 1. This is in sharp contrast with the effect of hadronic interactions whose cross sections, especially for inelastic processes, increase with energy and thus lead to increased hadron suppression and azimuthal anisotropy at large p_T. Therefore, the p_T dependence of hadron spectra suppression and azimuthal anisotropy is a unique signal of parton scattering and energy loss in the early stage of heavy-ion collisions.

Footnotes and References

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